National Aeronautics and Space Administration

Upper Troposphere/Lower Stratosphere (UTLS) Trace Gas Evolution in Recent Satellite Datasets: Relationships to the Subtropical Jet and Tropopause.

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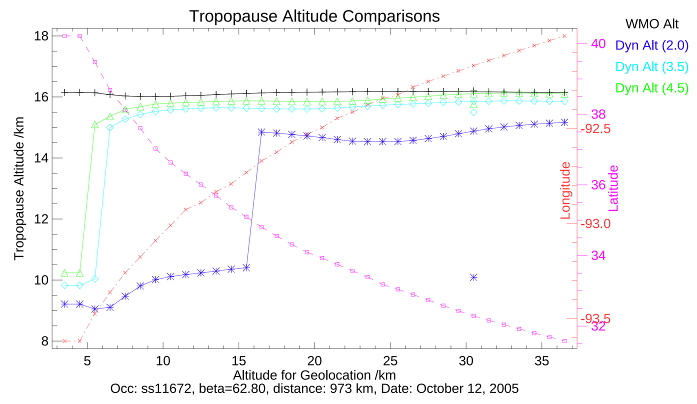
Introduction

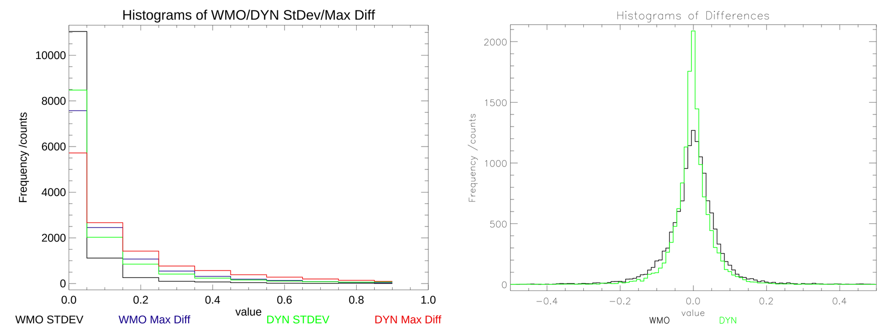
A method is being developed of categorizing the location and characteristics of upper tropospheric jets and the lower part of the stratospheric polar night jet that can extend into the lowermost stratosphere. We are using this method to define the position, width and dynamical characteristics (e.g., windspeed/direction, potential vorticity, temperature, static stability, etc) of the multiple jets in the upper troposphere (UT). A similar characterization is being done of the lower part of the stratospheric polar night jet. In addition, the tropopause is characterized using both WMO (temperature gradient) and dynamical definitions based on several potential vorticity (PV) values; locations with multiple tropopauses are identified and the position of the tropopauses with respect to the jets is determined. We show examples of these calculations using Goddard Earth Observing System Data Version 5.1.0 (GEOS-5) analyses, and how the jet and tropopause structure relates to Aura Microwave Limb Sounder (MLS) measurements.

1 Tropopause Calculations and Sensitivity Tests

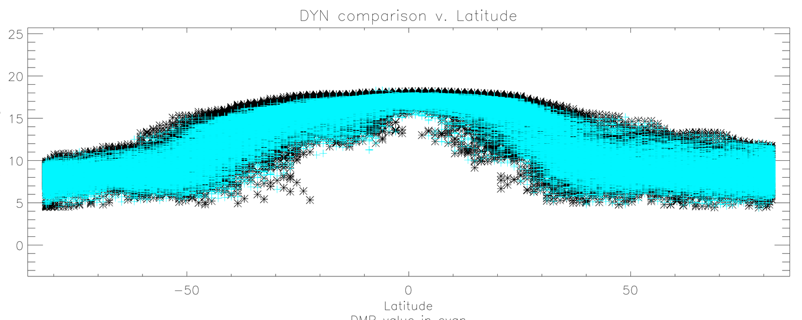
- WMO and "dynamical" tropopauses are calculated from the GEOS-5 analyses on the original model levels after interpolation to the latitudes and longitudes of the MLS and ACE-FTS data
- Dynamical tropopauses are at 2.0, 3.5 and 4.5 PVU, joined to 380 K in the tropics where the PV contour rises above that isentrope
- Multiple tropopauses in a profile are cataloged (dashed lines in Section 1 and Section 3 examples show secondary one)

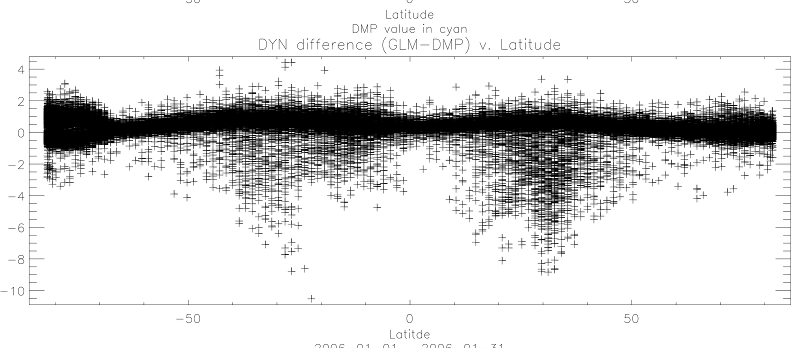


- As well as depending on the tropopause definition, tropopause calculations can also depend strongly on the exact location and on the vertical grid used; we are therefore conducting extensive sensivity tests to examine these dependencies:
  - ACE-FTS data are being used to test sensitivity to exact location and vertical grid – the figure above shows an extreme case for an occultation where the tangent-point latitude and longitude change substantially with altitude
  - Lines show the WMO, 2.0, 3.5, and 4.5 PVU tropopauses (black/crosses, blue/stars, cyan/diamonds, green/triangles) calculated at the latitudes (magenta) and longitudes (red) of the ACE data at each altitude between 3.5 and 36.5 km on its 1-km grid; solitary symbols show the tropopause calculated from the "profile" after interpolation to the ACE 3-dimensional locations (on the 1-km grid)



- Most cases show much less sensitivity:
  - Above left plots show histograms of the maximum different in tropopauses calculated at each of the 34 levels in an occultation, for a set of over 12,000 ACE occultations; most differences are less then 0.3 km, nearly all less than 0.8 km
  - Above right plot is histogram of the difference in the "best" tropopause from the 34-level calculations (the average of the two value at positions for altitudes closest to the average over the 34 levels) and the tropopause calculated after interpolation to the 3D positions for the occultation; most differences are less than 0.2 km, and the symmetry suggests no persistent bias



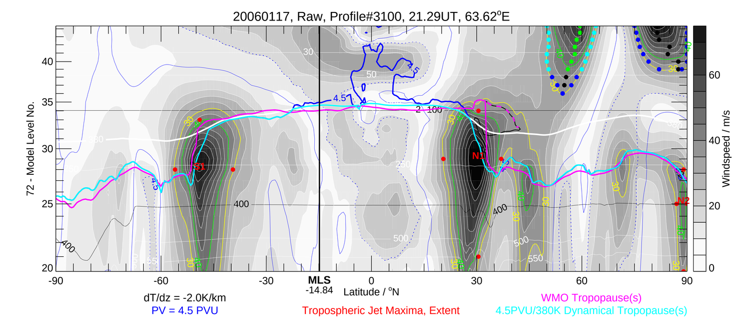


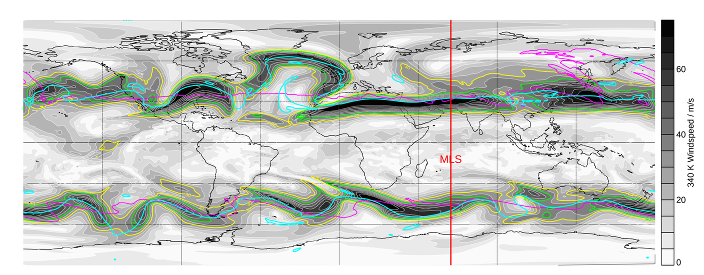
- Comparisons with the tropopauses in the current derived meteorological products [DMPs; Manney, et al, 2007, JGR] show good agreement, as seen in above plot for MLS for the January 2006 3.5 PVU dynamical tropopause (slight low bias of original DMPs, cyan, is from different calculation of altitude from pressure), with significant differences confined to regions of high sensitivity near UT jets and in SH polar regions

4 Continuing Work/Plans

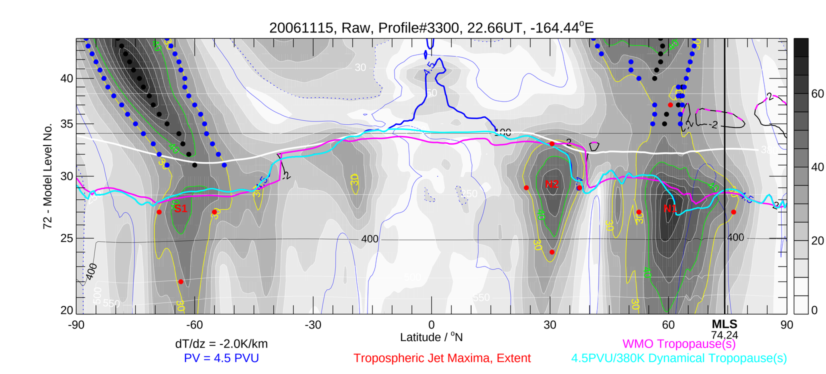
- The jet characterization and multiple tropopause calculations from GEOS-5 and other meteorological analyses are being used to create a climatology exploring the relationship/interactions between the UTJs, the PNJ and the tropopause; comparisons between different analyses will help assess the robustness of these definitions
- The locations of satellite observations with respect to UTJs and PNJs will be calculated and cataloged for the complete ACE, Aura MLS and HIRDLS missions (and eventually other datasets such as POAM, SAGE, HALOE), along with detailed tropopause information and other products interpolated to or calculated at the MLS and ACE locations
- This information will be used in detailed studies of the relationship of satellite observations to the tropopause, UTJ and PNJ structure and evolution
- When completed, we plan to make these products public to facilitate UTLS studies and to extend the currently available "Derived Meteorological Products" [Manney et al, JGR, 2007, 112, D24S50, doi:10.1029/2007JD008709] (primarily intended for stratospheric data analyses) to characterization of the UTLS

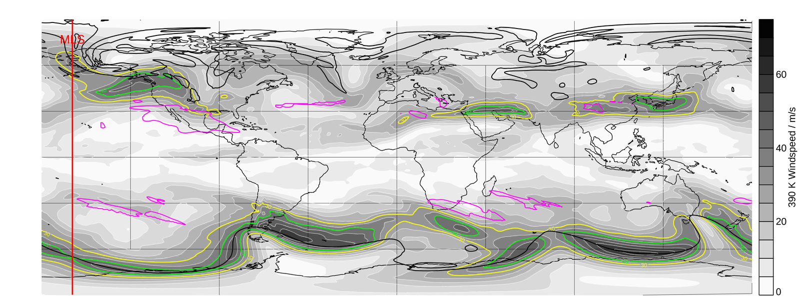
2 Characterization of Upper Tropospheric and Stratospheric Jets





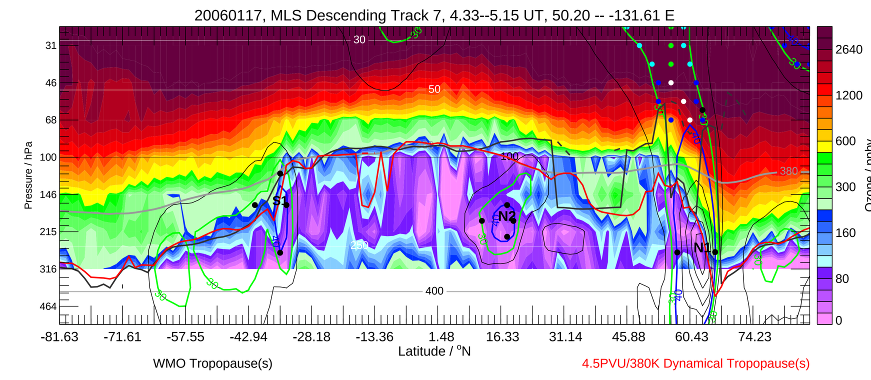
- Upper tropospheric jet (UTJ) cores are defined on "slices" at a given longitude by windspeed maxima over 40 m/s in the region between 400 and 100 hPa
- Vertical and horizontal edges of UTJ regions are defined by 30 m/s windspeed
- Red dots show edge and red letters core locations (increasing number with decreasing strength)
- The lower levels of the polar night jet (PNJ) core and edges are characterized at each longitude at each level by the most poleward westerly jet maximum with windspeed over 30 m/s, and the location where the windspeed drops below 30 m/s
- When the vortex is shifted entirely off the pole, there is an easterly jet poleward of the westerly one, representing the opposite edge of the polar vortex, which is characterized in the same manner (e.g., 17 Jan 2006 example)
- At levels where both UTJs and a PNJ exist, the bottom of the PNJ is defined as the level below which the windspeed shifts from decreasing to increasing with decreasing height
- Black and blue dots show core and edges; when PNJ crosses longitude twice, green and cyan dots show second crossing
- Locations (latitude, altitude, pressure) and values of dynamical variables (U, V, T, PV, dT/dz, relative vorticity) at UTJ core and edge locations are cataloged
- As are distances from the primary WMO and dynamical tropopause locations (see Section 2)
- The examples shown here are at longitudes corresponding to that of a single MLS profile (the red line on the maps, with "MLS" at the latitude of the MLS measurement)
- The distances of MLS and ACE-FTS measurements from PNJ and STJ locations will be cataloged for future use in relating MLS fields to jet characteristics
- Both examples show a complex pattern of UTJs, with large tropopause changes across the "subtropical jet" (typically the most equatorward strong jet)
- The 17 Jan 2006 340 K map shows the pattern of this complex structure near the altitude of typical UTJ maxima
- The 15 Nov 2006 example shows cases (both decaying SH jet and developing NH jet) where the bottom of the PNJ merges with the top of one UTJ
- The 390 K maps for 15 Nov 2006 (heavy black line in polar regions shows PV value typical of edge of the lowermost vortex) show the wind patterns transitioning to a more zonal structure representative of the PNJ with increasing altitude (contrast with 340 K map shown in 17 Jan 2006 example)

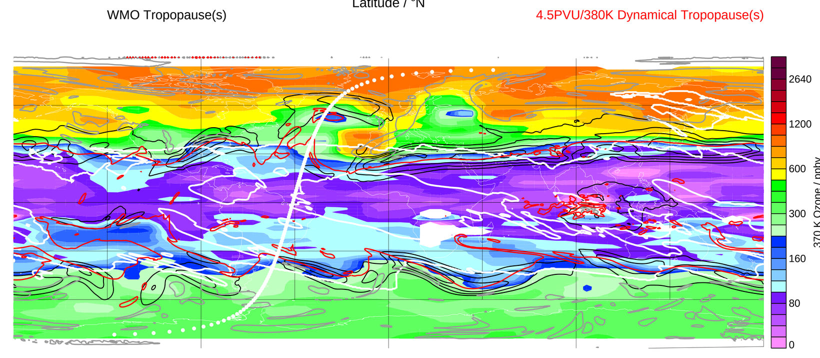




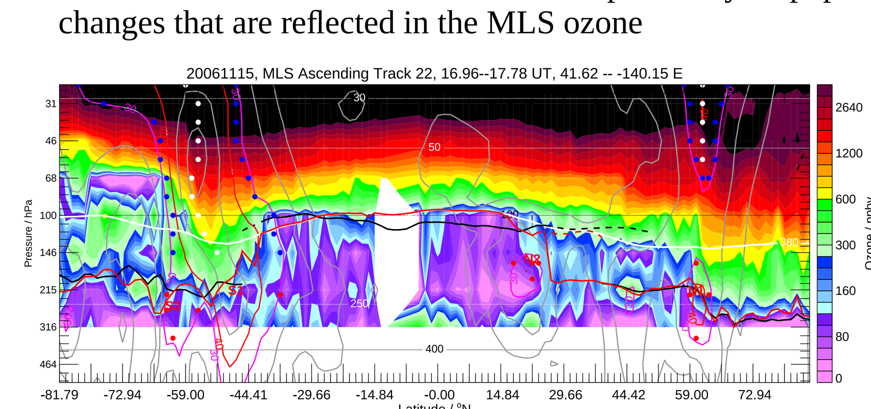
3 MLS Measurements In Relation to Jets and Tropopauses

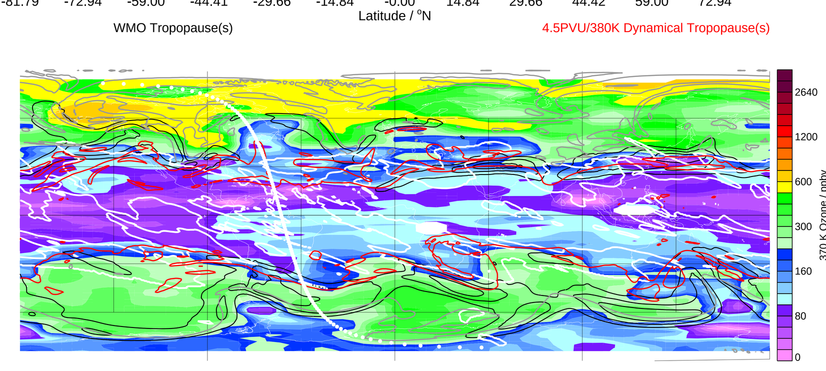
The machinery for characterizing the UTJs and PNJ does not depend on the "slice" being along a longitude. In addition to using this in the future to facilitate more 3-dimensional characterization, we show here examples where the slices are individual MLS orbit tracks; the track for the cross-section is shown on the 370 K ozone maps accompanying them.



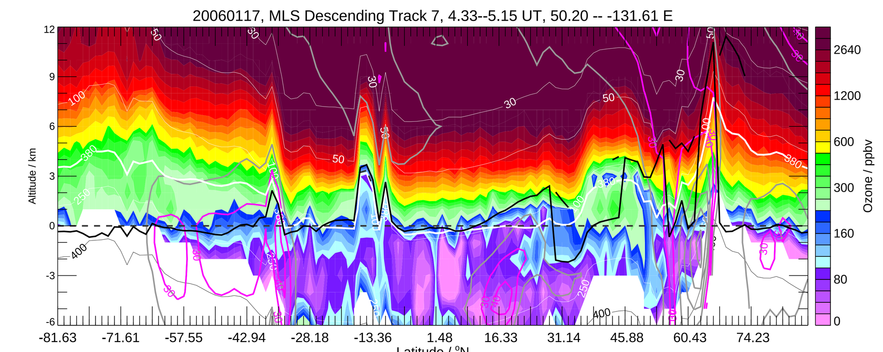


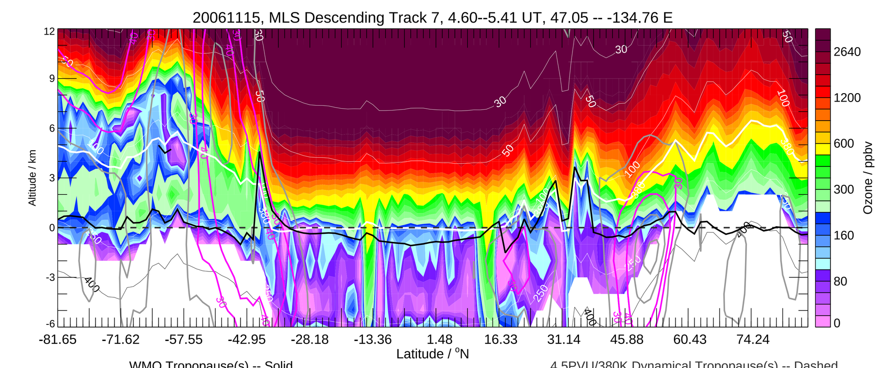
- The MLS track shown on 17 Jan 2006 cuts through the UT ridge that forced the 2006 major stratospheric sudden warming [e.g., Coy et al, submitted to JAS]
  - The strong UTJ is shifted to high latitude (see 340 K windspeeds in Section 1), directly under the equatorward edge of the PNJ that is increasingly shifted off the pole with increasing altitude (easterly jet near pole at highest levels shown here)
  - The tropopause rises abruptly over the strong, narrow UTJ, and drops sharply poleward of it; MLS ozone echoes these changes
  - Equatorward of the UTJ, there is a double WMO tropopause and a local minimum in MLS ozone at levels in between them, consistent with behavior previously reported in regional (e.g., aircraft) observations
  - The weak UTJ in the SH is also accompanied by tropopause changes that are reflected in the MLS ozone



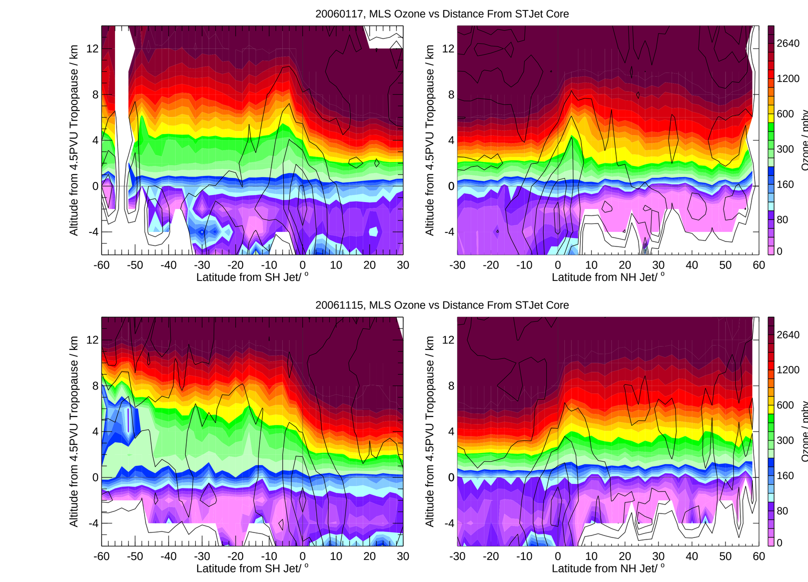


- Santee et al [paper in preparation] show that on 15 Nov 2006 the PNJ and UTJ in the SH merged in averages around equivalent latitude contours.
  - The 370 K maps here show the dynamical tropopause (red) and lowermost vortex edge (grey) following either side of the strong jet, which transitions to a more zonal PNJ at and above 390 K (Section 1 map); the MLS track runs inside the lowermost vortex near its edge at its highest latitudes
  - The tropopause drops from near 100 hPa equatorward of the broad UTJ region to below 250 hPa poleward of it, with MLS ozone showing strong vertical gradients across the tropopause not only outside the vortex, but inside/beneath it as well
  - In the NH, the PNJ is beginning to form and is apparent at this longitude, with higher ozone along its inside edge as expected from descent
  - In the large region (∼20 to 50°N) with a double WMO (and dynamical over part of the region) tropopause (dashed black line in cross-section; thick white line on map shows where primary tropopause crosses 370 K), MLS ozone again shows a local minimum between the tropopauses

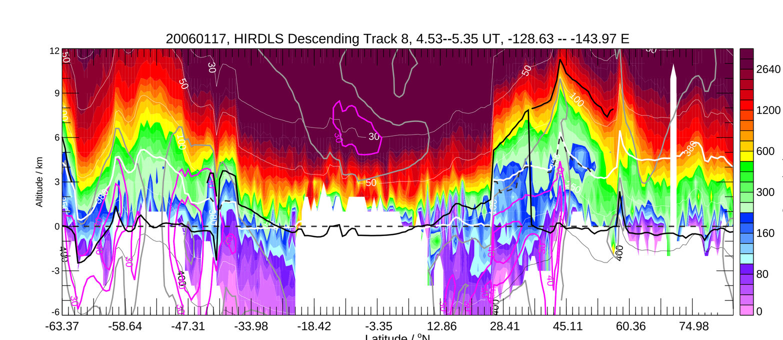




- The above figures show the same MLS orbit track ozone cross-sections on 17 January 2006 and 15 November 2006, but now the vertical coordinate is the distance (km) from the 4.5 PVU tropopause
  - Grey and magenta overlays show windspeeds (30 m/s magenta) at 10 m/s intervals; thin white lines show pressure levels, thick white line 380 K potential temperature contour
  - Similar plots with WMO tropopause as a coordinate (not shown) have large discontinuities near the UTJs, since the tropopause defined that way shows large, sudden changes there
  - This view highlights differing ozone gradients above the tropopause in different regions: Strongest gradients are in the tropics and subtropics, only slightly weaker in the NH winter, and considerably weaker in summer polar regions (especially SH)
  - The SH polar regions on 15 November 2006 show remnants of processed air filling the region between the residual PNJ and the strong UTJ; while some low ozone below the level of the PNJ appears to originate from this stratospheric source, it is impossible to tell from this single snapshot whether the low ozone at highest latitudes at tropopause level is tropospheric or stratospheric in origin [Santee, et al, in preparation, show evidence of ascent in the polar regions at/before this time]



- The above figures show all the MLS ozone data on 17 January 2006 and 15 November 2006, mapped with a vertical coordinate of distance from the 4.5 PVU tropopause, and a horizontal coordinate of latitudinal distance from the primary (strongest) UTJ
  - Black overlays are windspeeds (by 10 m/s) binned and averaged in same way as MLS ozone
  - As was apparent in the cross-sections relative to the tropopause, the ozone value at tropopause level is nearly constant
  - Again, the strong ozone gradients above the tropopause equatorward of the UTJ, and poleward of it in the NH winter are highlighted, with weak gradients in the SH in both summer and fall
- In the UTLS, where the equivalent latitude/potential temperature coordinates commonly used to characterize different air masses become less useful, viewing the data with respect to the UTJs and the tropopause can provide a way to average similar air masses and thus produce a climatology of the behavior of ozone and other trace gases in similar air masses.



- We are starting the same kind of analysis using HIRDLS data, as shown in the orbit section above of HIRDLS ozone with tropopause vertical coordinate
- Note clear region of low ozone between double WMO tropopauses; HIRDLS vertical resolution will be valuable in better defining such features
- More detailed studies of HIRDLS UTLS ozone are given in talks/posters by B.Nardi, J.Gille, M.Olsen
- Similar tools have been developed and are being tested for characterizing ACE-FTS data with respect to the UTJ and PNJ locations